Journal of Geoscience and Environment Protection, 2016, 4, 74-79
Published Online April 2016 in SciRes. http://www.scirp.org/journal/gep
http://dx.doi.org/10.4236/gep.2016.44010

Investigation the Risk of Spontaneous Combustion in Barapukuria Coal Mine, Dinajpur, Bangladesh

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Received 24 February 2016; accepted 23 April 2016; published 26 April 2016

Abstract

Spontaneous combustion of coal is one of the major problems in the coal mine. The fire may occur due to exogenous and endogenous causes, by which coal liberated heat to the air or heat absorbed into it. It causes loss of production, as well as economical or financial losses and polluted the environment. If, the heat liberated during this process is allowed to accumulate, the rate of reaction increases exponentially and there is a further rise in temperature that generates the flame and produce CO, CO_2, CH_4, N_2, O_2 etc. In addition, the heat generated within coal affected by different factors such moisture, ash, volatile matter etc. of coal. This paper deals with the oxidation and spontaneous combustion risk in Barapukuria underground longwall coal mine, Dinajpur, Bangladesh. In this study, the laboratory analyses (proximate analyses) shows the inherent and the total moisture content value is average 2.73% and 5.82% to 12.75%, respectively. It indicates that these moisture contents are moderately liable to self heating. The less ash content value (av.13.2%) shows, it is less liable to spontaneous combustion. In addition to this, the temperature and concentration of some mine gases (CO, N_2, O_2) were monitored to calculate the Graham's ratio. According to Graham's ratio, the longwall faces have high oxidation risk and medium combustion risk. Therefore, the actual control of spontaneous combustion of coal is important to save coal mine from mine fires and also provides a real opportunity to improve the financial performance of the overall organization.

Keywords

Spontaneous Combustion, Proximate Analyses, Underground Temperature, Graham's Ratio

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How to cite this paper: Ahamed, S., Monir, M.U., Biswas, P.K. and Khan, A.A. (2016) Investigation the Risk of Spontaneous Combustion in Barapukuria Coal Mine, Dinajpur, Bangladesh. *Journal of Geoscience and Environment Protection*, **4**, 74-79.
http://dx.doi.org/10.4236/gep.2016.44010

1. Introduction

Barapukuria coal mine is the only one developed coal mine in Bangladesh, containing 389 mt reserves (demonstrated 303 and inferred 86) [1] [2]. The Barapukuria Coal Basin is located at the stable platform of northwestern part of Bangladesh. This basin contains Permian aged coal of Gondwana group that consists of six coal seams (I-VI), among them the lower most seam VI is being mined. Every coal mine has a number of hazards because of their geological, mining and many other factors. Auto-oxidation or spontaneous combustion of coal is a serious problem that leads various safety problems in mining, long distance transportation and storage areas as well as economic losses [3] [4]. It is a self heating process that occurs when oxygen reacts with coal without influences of any external heat by which it produces various toxic gases likely CO, CO_2, CH_4 and water vapor [5]-[8] that are harmful for any kind of coal mine and decomposition of these materials leading to the liberation of heat [9].

However, different researchers investigated that auto oxidation process depends on many intrinsic and extrinsic properties of coal such as coal rank or type of coal, temperature, exposed surface, amount of air passing over the coal, porosity and permeability, moisture content, amount of sulfur, particle size of coal etc. [10]-[16].

The investigation on spontaneous combustion in Bangladesh is limited. Therefore, the objective of this study is to investigate the risk of auto-oxidation or self heating by using laboratory scale analysis and industrial scale work (Graham's ratio) in Barapukuria Coal Mine (BCM), Dinajpur, Bangladesh.

2. Materials and Methods

2.1. Study Region

The Barapukuria coal mining company (BCMC) is located near the Barapukuria village of Hamidpur union council under Parbatipur thana, Dinajpur district. The study area and its adjoining area is situated at the northern part of Bangladesh and the area lies between latitudes 25,031'N to 25,035'N and longitude 88,057'E to 88,059'E (shown in **Figure 1**) included in the survey of Bangladesh topographic sheet No. 78 c/14. **Figure 1** shows the location of study area.

2.2. Sample Collection

A total twelve coal samples were collected from Barapukuria coal Mine during December, 2013 among them five are collected from coal face (CF1-5) and seven from stockpile (SP4-10) by channel sampling method. The collected samples are crushed as per the experimental requirements then sieved to required sizes and stored in air tight containers for further use in experiments.

2.3. Sample Analyses

Proximate analyses of these samples were carried out at Institute of Mining, Mineralogy and Metallurgy (IMMM), Bangladesh in accordance with standard specifications (British Standard or American Society for Testing and Materials, ASTM), to investigate the susceptibility of spontaneous combustion of coal.

2.4. Determination Method for the Risk of Spontaneous Combustion

In order to determine the risk of auto oxidation the temperature of underground are continuously monitored from Decembar, 13 to July, 14. To carried out the industrial scale work (Graham's ratio) the concentration of some mine gases (CO, N_2 and O_2) were collected from the Barapukuria Coal Mine that were measured in a regular basis by which Graham's ratio was calculated to determine the oxidation and combustion risk in according to [17]. The Graham's ratio of Barapukuria Coal was calculated by the following equations [17]:

$$GR = \frac{100 \times \mathrm{CO}}{\frac{20.93}{79.04} \times \mathrm{N}_2 - \mathrm{O}_2} \text{ or, } GR = \frac{100 \times \mathrm{CO}}{0.265 \times \mathrm{N}_2 - \mathrm{O}_2}$$

3. Results and Discussion

In Barapukuria Coal Mine (BCM), coal is extracted from 1st slice of seam vi (six) by using Multislice Longwall

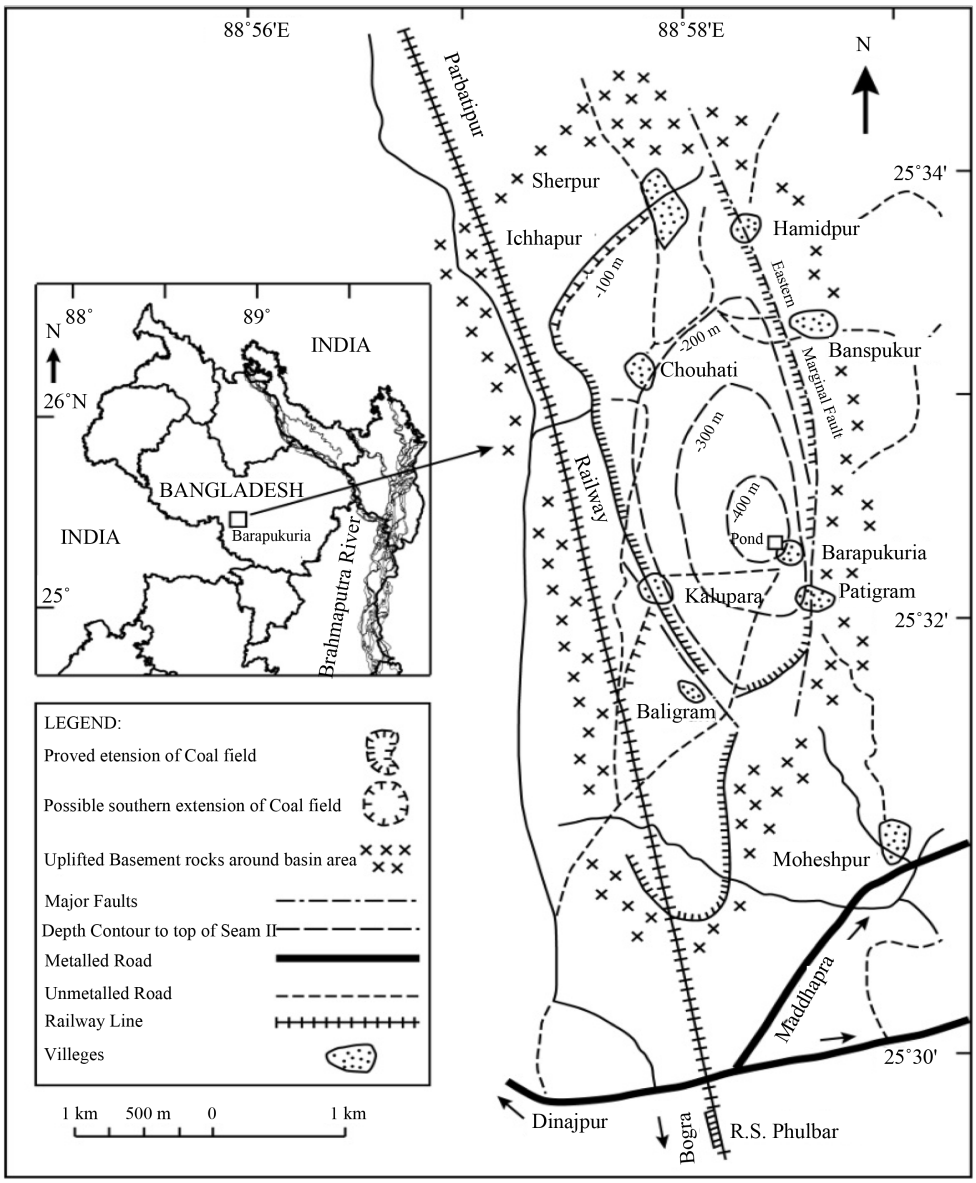

Figure 1. Location map of study area. [1] compiled from WA, 1991).

mining method. After finished the production of 1st slice coal, production of 2nd slice is commercially started from December/13 to present by applying Multislice Longwall top coal caving (LTCC) method to enhance the production rate.

During the production of 1st slice of coal faces are affected by many difficulties and accidents, spontaneous combustion is one of them. The 1st slice of 1110 Longwall face is started coal production on 10th September, 2005 but spontaneous combustion occurred in this coal face and abnormal presence of CO was detected with abnormal water in rush. As a result, production operation was terminated and this face was sealed off with the equipment when the presence of toxic carbon monoxide (CO) gas was reached at about 6000 ppm [18]. The effect of spontaneous combustion (heat generate due to auto-oxidation) is also seen in the surface coal stockpiles (**Figure 2**) which creates smoke in coal stockpiles that is ineffectual for coal mine industry.

In order to investigate the spontaneous combustion of coal proximate analyses of Barapukuria coal was carried out and the temperature of longwall faces with the concentration of some mine gases (CO, CH_4, CO_2, O_2 and N_2) were collected from Barapukuria coal Mine, Dinajpur, Bangladesh.

Figure 2. Smoke produced by the action of self-heating of coal in Barapukuria coal stockpiles, (a) smoke found in the pick of the coal stockpile, (b) smoke produced through crack that occur during loading coal.

The proximate analysis results of Barapukuria coal samples are shown in **Table 1**. Moisture in coal contributes to spontaneous heating because it assists the oxidation process and its mainly dependent on the inherent moisture content should be limited to 3% [7]. The analyzed samples have contains 2.73% (av.) moisture content these are suggesting that, the Barapukuria coal are liable to self heating process and total moisture content have medium value (5.82% to 12.75%) indicates that these coal are moderately liable to self heating.

Ash content of coal is an important factor to identify the possibility of spontaneous combustion of coal [7]. Generally, ash content are decreases the liability of coal to self heating that means the higher ash content decreases the liability and lower is increases. The value of this studied samples (CF-1, CF-2, CF-3) have higher ash content but the other samples shows the medium value (av. 13.2%). The results of volatile matter are medium to high (**Table 1**) which shows that it has low to medium susceptible to spontaneous combustion.

In addition, continuous monitoring records of underground temperature data were collected to investigate the effect of temperature to influence auto-oxidation that may cause the spontaneous combustion in underground. The average temperature in April and May months are recorded 41˚C and 37˚C respectively. The temperature is gradually decreases during June-July month. In Bangladesh, the April and May month is the summer season, the humidity in atmosphere is high in this season that may cause to increase the oxidation process of coal. The concentration of CO, N_2 and O_2 concentration was recorded besides with measuring the temperature in underground. The value of CO, N_2 and O_2 was carried out to calculate the Graham's ratio. The results of Graham's ratio are shown in **Table 2**. According to Ozdeniz *et al*. (2014) [8] shows different ranges of combustion risk for longwall coal mine that are shown in **Table 3**.

In this study, the average concentration of N_2, O_2 and CO are 40%, 24% and 0.001% respectively are recorded in underground. Graham's ratio was found 1.2, 1.64, 0.97, 1.34, 0.33 and 0.38 (**Table 2**) by using the gas concentration. In 14th May, the value was found 1.12. According to Graham's ratio scale (1 to <2) (**Table 3**) this value shows, there is combustion risk in coal face. After ten days, 24th May the ratio was calculated to be 1.64 that is higher than the previous day. So, it shows the face is in more combustion risk. The value of Graham's ratio 0.97 was calculated in the 4th June. This indicates the oxidation risk in longwall face. The value 1.34 is also indicates combustion risk due to gas concentration. In the last week of June month and the fast week of July month Graham's ratio was calculated to be 0.33 and 0.38 which indicated that there is no risk in underground as well as the longwall face is safe.

4. Conclusion

Laboratory scale Proximate analysis of Barapukuria coal shows that the value of inherent moisture content is 2.73% and the total moisture content value 5.82% to 12.75% suggesting that, these coal are moderately liable to spontaneous combustion, but the ash content (av. 13.2%) indicates that it is less responsible to self heating. Industrial scale analyses were carried out to investigate the risk of self heating by monitoring the temperature and some gas concentration in underground. The temperature was recorded (av. 41˚C to 37˚C) that is high and also

Table 1. Proximate analyses results of Barapukuria coal.

Sample No.	Surface moist. (%)	Inherent moist. (%)	Total moist. (%)	Ash (%)	Volatile matter (%)	Fixed Carbon (%)
CF-1	4	1.82	5.82	18.19	29.79	46.2
CF-2	4	1.9	5.9	17.36	23.56	53.18
CF-3	4.4	2.33	6.73	19.54	20.63	53.1
CF-4	10.84	1.91	12.75	14.17	23.39	49.69
CF-5	9.5	1.84	11.34	8.27	27.16	53.23
SP-4	7.69	2.36	10.05	20.88	24.75	44.5
SP-5	7.66	2.89	10.55	11.69	24.75	50.03
SP-6	7.7	3.12	10.82	12.29	24.75	50.86
SP-7	7.63	2.59	10.22	12.95	24.75	48.97
SP-8	7.89	2.46	10.35	12.18	24.75	56.16
SP-9	7.77	2.07	9.84	14.25	24.75	49.12
SP-10	7.62	2.46	10.08	13.14	24.75	53.26

Table 2. Graham's ratio of Barapukuria underground coal mine.

Date	Graham Ratio
14.05.14	1.12
24.05.14	1.64
04.06.14	0.97
14.06.14	1.34
24.06.14	0.33
04.07.14	0.38

Table 3. Graham's ratio scale [8] (Ozdeniz *et al*., 2014).

Graham's ratio	Comments
<0.2	No risk
0.5 - 0.7	Oxidation risk
1.0	Combustion risk
2.0	High combustion risk
3.0	Open fire or definitely combustion

risk for longwall. Graham's ratio was found 1.2, 1.64, 0.97, 1.34, 0.33 and 0.38 by using some gas (CO, N_2, O_2) concentration. These values signify that the longwall faces have high oxidation risk and medium combustion risk. So, it suggests that, the actual precautionary remedy against fire will increase the safety of mine. Proper identification of fires and its dealing will diminish the overall loss of coal production.

Acknowledgements

The authors are grateful to the authority of Barapukuria Coal Mining Company Limited (BCMCL) to giving the permission for collecting samples and providing valuable data to completing this work. Also, thanks to the authority of Institute of Mining, Mineralogy and Metallurgy (IMMM) of Joypurhat, Bangladesh for support to access to analytical laboratory.

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